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THE AIR POLLUTION SITUATION IN TERRE-HAUTE, INDIANA WITH SPECIAL REFERENCE TO THE HYDROGEN SULFIDE INCIDENT OF MAY-JUNE, 1964

Public Health Services
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THE AIR POLLUTION SITUATION IN TERRE HAUTE, INDIANA WITH SPECIAL REFERENCE TO THE HYDROGEN SULFIDE INCIDENT OF MAY-JUNE, 1964

A joint report to the City of Terre Haute by

U.S. Public Health Service
Division of Air Pollution

and

Indiana Air Pollution Control Board
Division of Sanitary Engineering

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U.S. Department of Health, Education, and Welfare
Public Health Service
Division of Air Pollution

June 19, 1964

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INTRODUCTION

Prompted by numerous reports of strong objectionable odors, illness, and paint darkening which began during the week end of May 9, 1964, the Mayor of the City of Terre Haute requested assistance from the Indiana State Board of Health and the U.S. Public Health Service, Division of Air Pollution to evaluate the air pollution problem. Pollution due to hydrogen sulfide, mercaptans and other malodorous compounds were strongly suggested by the nature of the effects, namely, quality of odor, paint damage and gastro-intestinal disturbances. In response to Mayor Tucker's request, a limited air pollution survey was conducted by the State of Indiana and the U.S. Public Health Service with the cooperation of the City of Terre Haute, during May 18 to June 15, 1964.

CONDUCT OF STUDY

Sequential samplers using lead acetate impregnated filter paper tapes were used to measure hydrogen sulfide at 5 sampling sites in the affected area, located in the southwestern part of the city (Figure 1). Consecutive 1-hour samples were collected daily. The minimum concentration detectable using this method is 0.2 parts per hundred million (pphm). A length of stain, hydrogen sulfide detector tube sampler was used to analyze grab samples in areas near sources where high concentrations of hydrogen sulfide were suspected (greater than 1 part per million (ppm)).

Wind direction and speed were determined using meteorological equipment installed at 2 locations in the affected area, namely, the Sarah Scott Elementary School and at the pumping station of the Sewage Treatment Plant. Additionally, meteorological information was obtained from the U.S. Weather Bureau Airport Station at Hulman Field, 6 miles from the area of concern.

Suspected sources of hydrogen sulfide emission were inspected in order to determine their potential to cause air pollution. Atmospheric hydrogen sulfide measurements were obtained near these sources using the detector tube sampler.

The geographic distribution of odor, paint damage, and reported health effects were delineated. Reports of adverse health effects and complaints of odors were investigated. Certain medical records such as mortality data, hospital emergency room records, and absenteeism were studied.

CONCLUSIONS

1. Concentrations of hydrogen sulfide in Terre Haute during the episodes of late May and early June 1964 were sufficient to cause public complaints and discomfort and paint blackening. Concentrations exceeding 30 parts per hundred million (pphm) were measured. Other odorous materials were observed by the study staff and the public.

2. Terre Haute has many potential sources of odorous air pollutants. Some or all of them may, at certain times, emit sufficient quantities of pollutants to cause public complaints and discomfort. In the recent episodes of late May and early June 1964, the most probable source of hydrogen sulfide and other odorous materials which caused the public complaints and discomfort and paint darkening was source #3. This was indicated by the relationship between measurements of hydrogen sulfide and odor observations and meteorological data and also by measurements of hydrogen sulfide made in the immediate vicinity of suspect sources.

There are sources of other pollutants in Terre Haute such as smoke and flyash which should be controlled.

3. Many public complaints about odors, health effects and property damage were made by citizens of Terre Haute during the current episodes. Investigation of the possible health effects of the air pollution revealed the presence of an air pollution problem with greater than nuisance value. The main symptoms reported by affected people included nausea, loss of sleep and abrupt awakening, shortness of breath and headache. However, almost none sought medical attention. In the opinion of medical observers, the hydrogen sulfide and other obnoxious odorous materials were the likely

cause of certain symptoms in exposed individuals. A "medical disaster" did not occur.

4. There is a pressing need for the establishment of an adequate air pollution control program in Terre Haute. The responsibility for doing so rests mainly on the local government. Suggested program activities include revision and enlargement of the smoke ordinance, air quality monitoring, pollution source abatement and regulation of new sources of pollution. Adequate personnel and funds should be provided to carry on the program on a continuing basis.

DISCUSSION OF RESULTS OF AEROMETRIC AND POLLUTION SOURCE STUDIES

A survey of principal sources of hydrogen sulfide and other malodorous compounds in the area revealed that the hydrogen sulfide emission potential was high at 3 sources (Table 1). The adjectival ratings for hydrogen sulfide emission potential are based upon such considerations as type of facility, number and nature of unit operations, problems which may be encountered in these operations resulting in accidental emission of hydrogen sulfide, and quality of sulfur compounds processed.

During this survey, atmospheric hydrogen sulfide concentrations were determined using hydrogen sulfide detector tubes (sensitivity = 1 ppm) in the vicinity of these potential sources. Out of about 50 samples, positive results were obtained only at the fence line, downwind of source #3, (Table 2). Strong hydrogen sulfide odors and the typical odor associated with source #3 were perceived in the City of Terre Haute at about the time of these measurements. Source #3 is a 36-acre lagoon used for the biodegradation of organic industrial wastes.

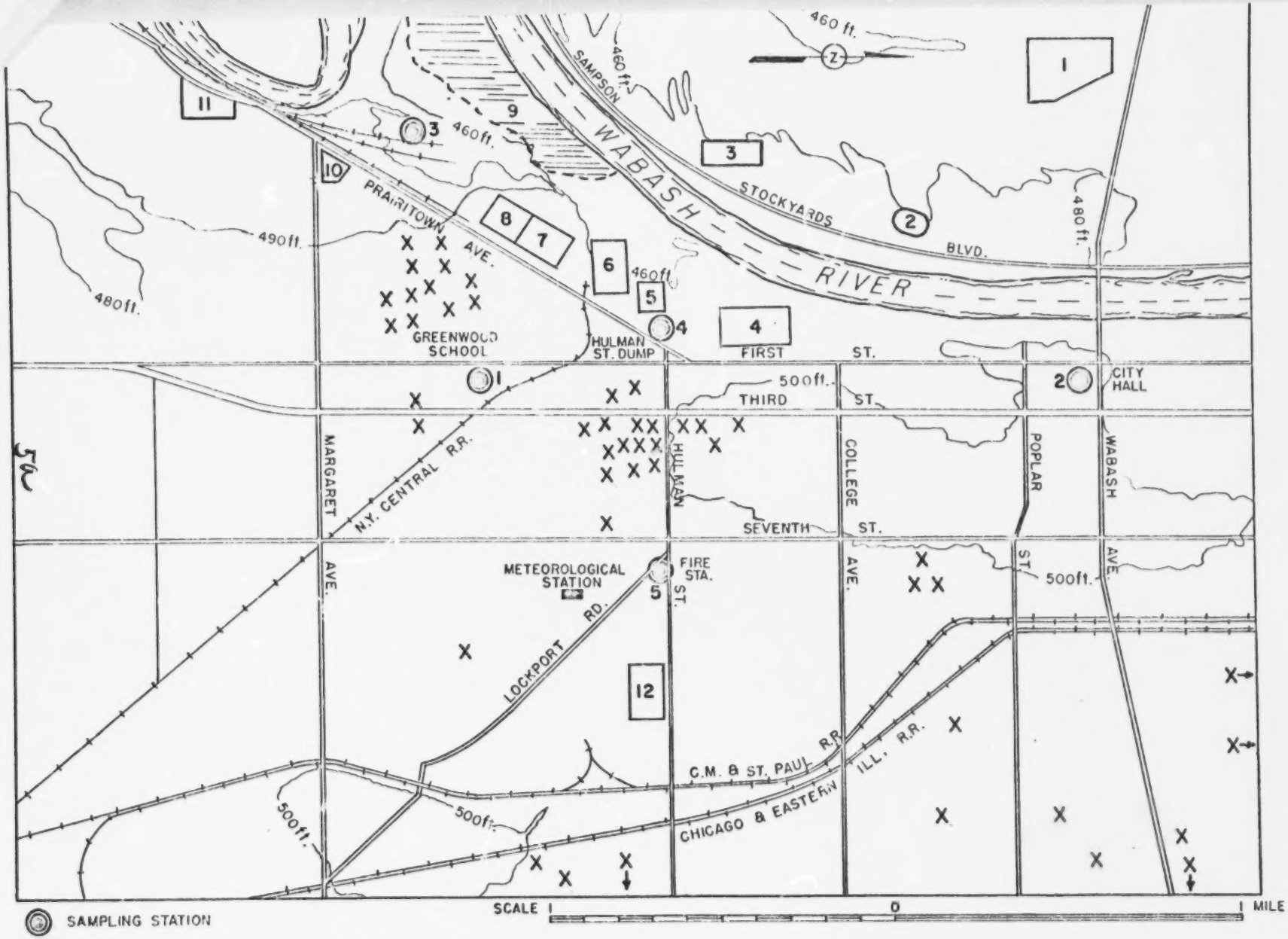


FIGURE 1. MAP OF AREA AFFECTED SHOWING SOURCES, SAMPLING SITES AND HEALTH COMPLAINTS.

Table 1. PRINCIPAL POTENTIAL SOURCES OF EMISSION OF HYDROGEN SULFIDE AND OTHER MALODOROUS COMPOUNDS

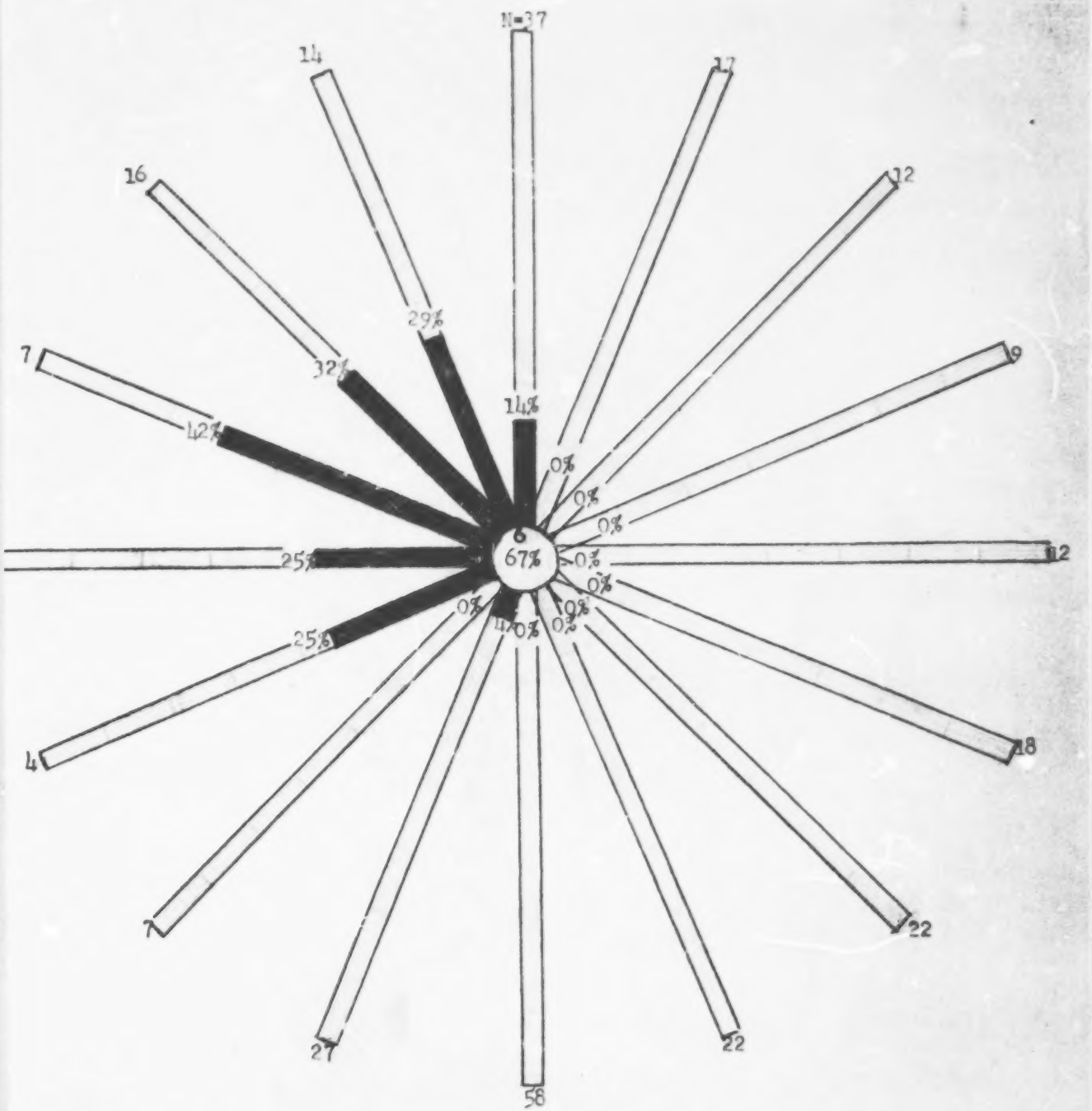
Source	H_2S Emission Potential	Description of prevalent odors
1. Dump (In Taylorville)	Low	Smoke, burning garbage
2. Septic tank dump	Medium	Privy, putrefaction
3. Commercial Solvents Corp. Lagoons	High	Privy, putrefaction, rotten eggs
4. Commercial Solvents Corp.	Low	Rotten fish
5. Hulman Street Dump	Low	Smoky, burning garbage
6. Weston Paper Co.	Low	Burnt, musty
7. Western Tar Co.	None	Coal tars
8. Indiana Wood Preserving Co.	None	Smoke, coal tars
9. Weston Paper Co., Spray Waste Area	Medium-High	Stagnant water
10. City Dump	Low	Smoke, burning garbage
11. Sewage Treatment Plant	Low	Sewage
12. Indiana Gas and Chemical Corporation	High	Smoke, Sulfurous, coal tar

Table 2. HYDROGEN SULFIDE CONCENTRATIONS GREATER THAN ONE PART PER MILLION
(Measured using the detector tube method)

Date, 1964	Time	H_2S (ppm)	Sampling site	Wind direction	Wind speed, mph
May 22	0300	2	Eastern section of fence line, source #3		Calm
May 24	1630	8	Eastern section of fence line, source #3	W	14
June 4	0400	5	Eastern section of fence line, source #3		Calm
June 10	0030	2	Northeastern section of fence line, source #3	SW	6

The frequency of occurrence of hourly hydrogen sulfide concentrations greater than 0.2 pphm obtained at each sampling site except #3 were related to wind direction (pollution roses, Figures 2A-D). The total number of samples collected at site #3 were insufficient to give a valid pollution rose. The wind data used in this analysis was obtained at the special meteorological station established at the Sarah Scott School except when these data were unavailable and airport data (Hulman Field) were used. The distribution of these data indicates the principal directions from which hydrogen sulfide pollution reaches the sampling site.

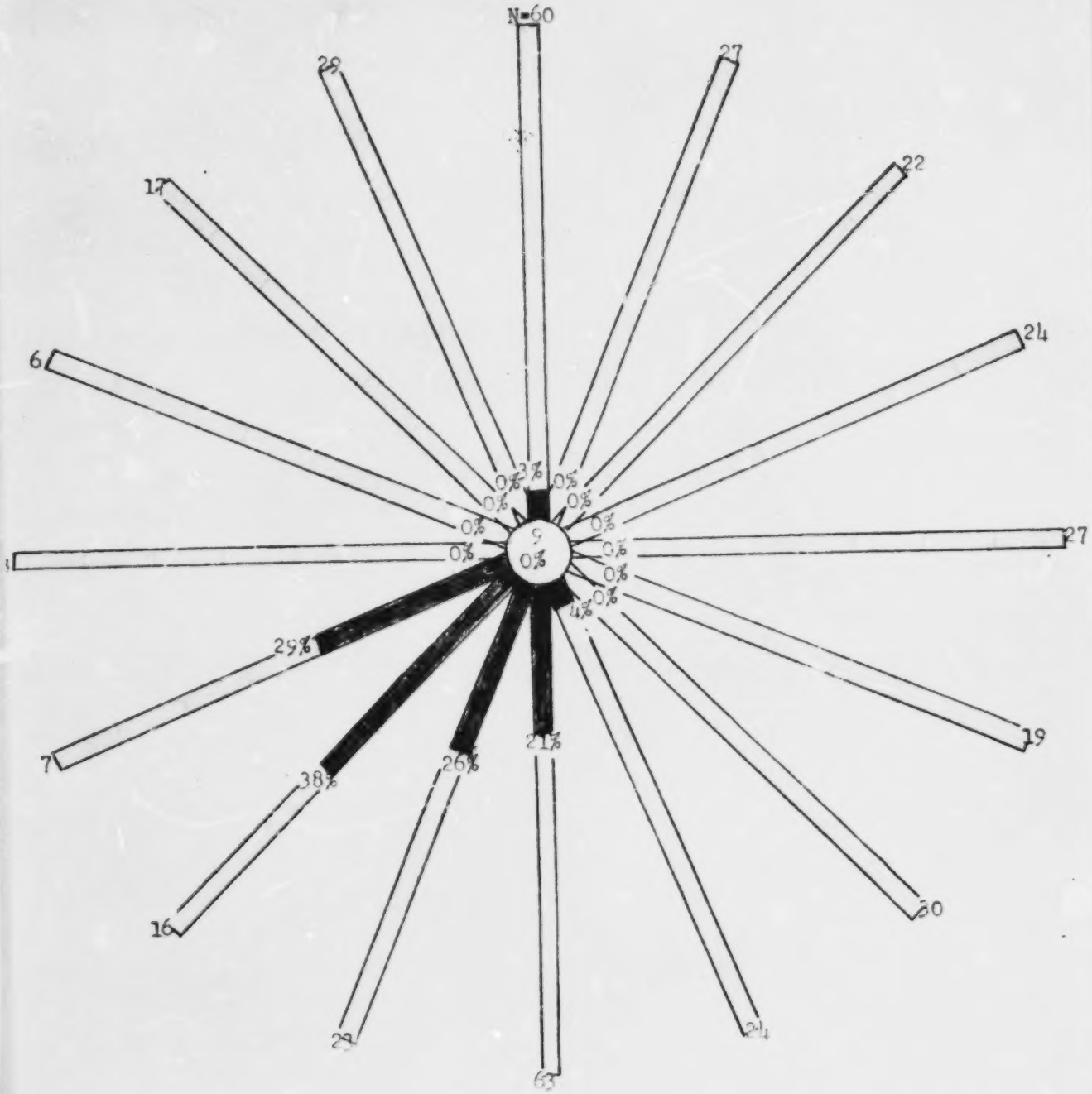
Pollution at site #1 occurred most frequently when the wind direction was west to northwest. This indicates that sources 1, 2, 3, 4, 5, 6, 7, 8 and 9 could have contributed to pollution at site #1, however, only sources 3 and 9 have high hydrogen sulfide emission potential and are therefore the most probable sources (Figure 1, Table 1). Pollution at site #2 occurred most frequently when the wind direction was southwest. This indicates that sources 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 could have contributed to pollution at site #2, however, only sources 3 and 9 have high hydrogen sulfide emission potential and are therefore the most probable sources (Figure 1, Table 1). Pollution at site #4 occurred most frequently when the wind direction was west-southwest through north-northwest. This indicates that sources 1, 2, 3, 4, 5, 6 and 9 could have contributed to pollution at site #4, however, only sources 3 and 9 have high hydrogen sulfide emission potential and are therefore the most probable sources (Figure 1, Table 1). Pollution at site #5 occurred most frequently when the wind direction was southwest to northwest. This



6a

N = number of hourly wind observations for each direction

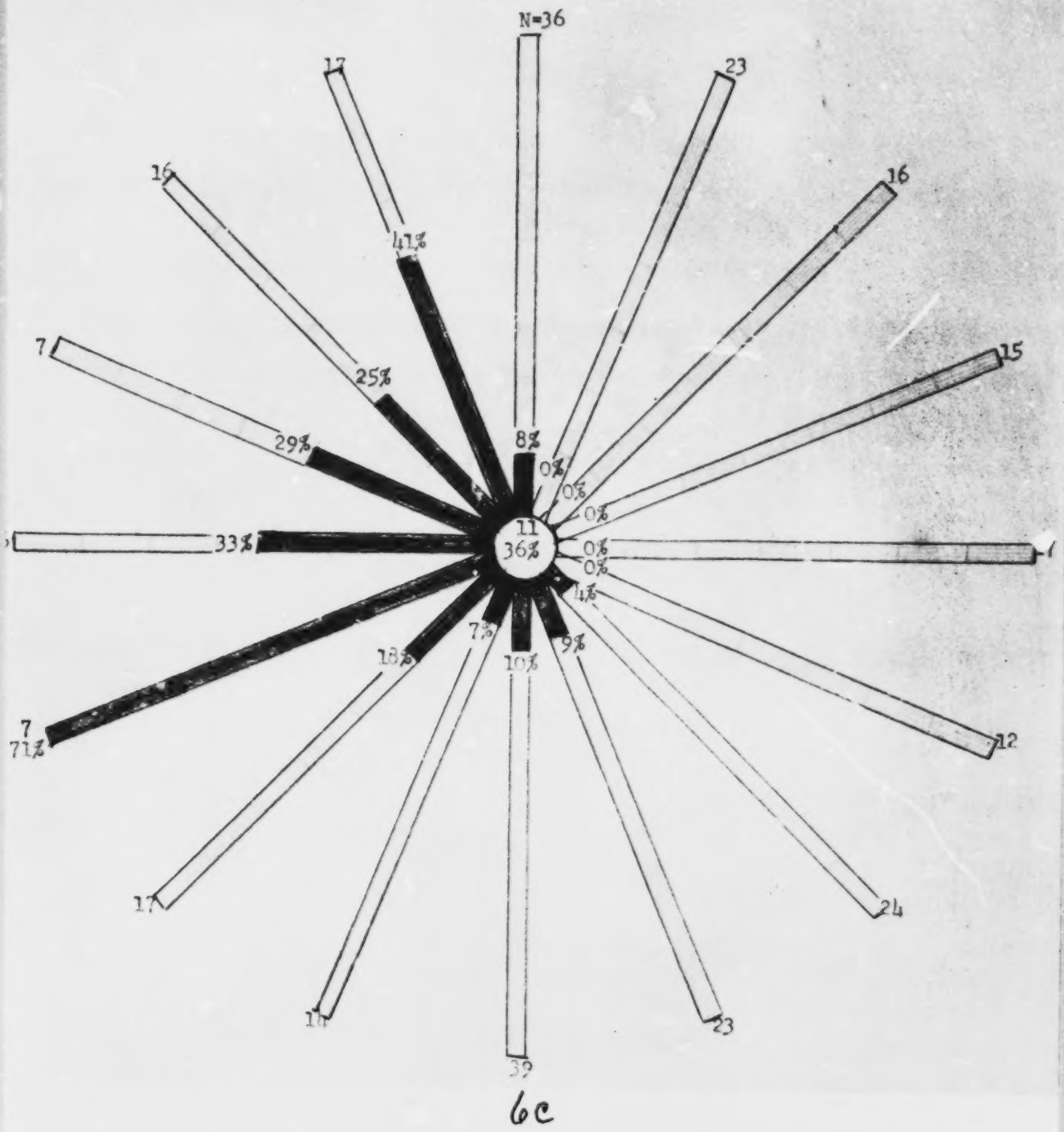
Figure 2A. PERCENT FREQUENCY OF OCCURRENCE OF H_2S CONCENTRATION GREATER THAN 0.2 PPHM FOR EACH WIND DIRECTION AT SAMPLING STATION NUMBER 1.



6b

N = number of hourly wind observations for each direction

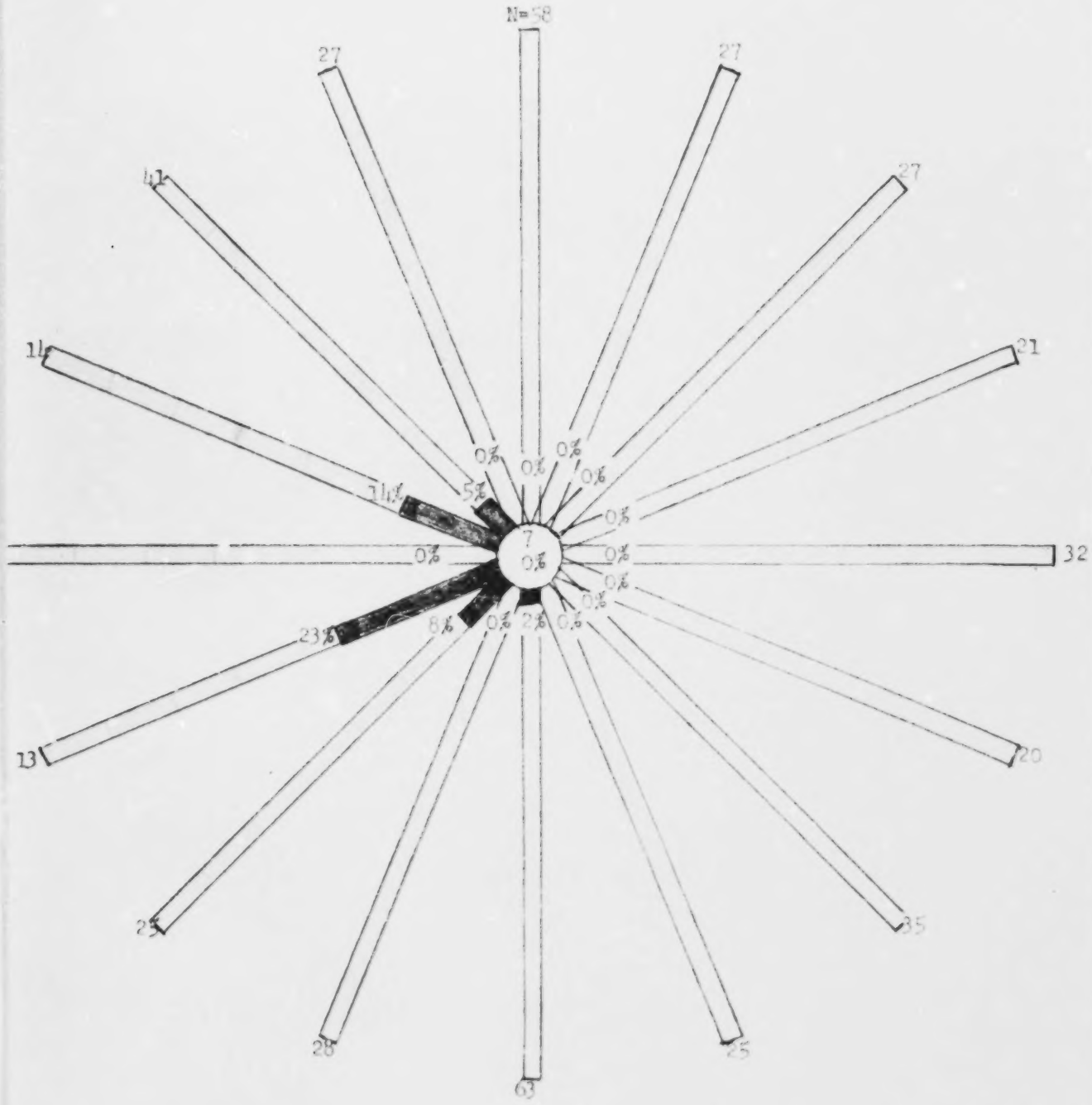
Figure 2B. PERCENT FREQUENCY OF OCCURRENCE OF H_2S CONCENTRATION GREATER THAN 0.2 PPHM FOR EACH WIND DIRECTION AT SAMPLING STATION NUMBER 2.



6c

N = number of hourly wind observations for each direction

Figure 2C. PERCENT FREQUENCY OF OCCURRENCE OF H_2S CONCENTRATION GREATER THAN 0.2 PPHM FOR EACH WIND DIRECTION AT SAMPLING STATION NUMBER 4.



6d

N = number of hourly wind observations for each direction

Figure 2D. PERCENT FREQUENCY OF OCCURRENCE OF H_2S CONCENTRATION GREATER THAN 0.2 PPHM FOR EACH WIND DIRECTION AT SAMPLING STATION NUMBER 5.

indicates that sources 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 could have contributed to pollution at site #5, however, only sources 3 and 9 have high hydrogen sulfide emission potential and are therefore the most probable sources (Figure 1, Table 1).

These pollution roses indicate that the most probable sources of hydrogen sulfide that affected the areas represented by the sampling sites in southwestern Terre Haute were sources 3 and 9.

No high concentrations of hydrogen sulfide were found by use of detector tubes in the vicinity of source #9. Thus, it is unlikely that source #9 played a major role in causing the high levels of hydrogen sulfide found in the community. Since high levels of hydrogen sulfide were found adjacent to source #3, it is evident that source #3 played a major role in causing high levels of hydrogen sulfide found in the community.

The odor threshold of hydrogen sulfide is about 2.5 pphm varying from 1 to 10 pphm depending upon the olefactory sensitivity of the respondent.[1] Paint blackening of lead base paint moistened with water occurs at hydrogen sulfide levels of about 10 pphm that persist for about 1 hour.[2] The State of California ambient air quality standard for hydrogen sulfide is 10 pphm for 1 hour.[3]

Reference to Table 3 which gives the frequency of occurrence of hydrogen sulfide concentrations in various ranges shows that the odor threshold at the city sampling sites was exceeded from 1 to 5.4 percent of the time. The area surrounding site #4 was the most affected area and the area surrounding site #5 the least affected. Sampling site #3 is excluded from consideration in this statement because a relatively small

Table 3. FREQUENCY OF OCCURRENCE OF STATED CONCENTRATIONS OF HYDROGEN SULFIDE

Sampling Site No.	Total No. of Hourly measurements	Concentration Range, pphm								
		Less than 0.2		0.2-1.9		2.0-9.9		Greater than 10.0		Hourly Max. concentration pphm
		Percent	No.[a]	Percent	No.	Percent	No.	Percent	No.	
1	296	92.5	274	5.4	16	1.4	4	.7	2	>30
2	406	92.6	376	3.7	15	3.2	13	.5	2	10
3	85	63.6	54	28.2	24	8.2	8	0	0	8.3
4	302	87.0	263	7.6	23	4.0	12	1.4	4	30
5	482	98.0	472	1.0	5	1.0	5	0	0	9

a. Number of hourly measurements in the stated concentration range.

number of samples were collected. The State of California ambient air quality standard was exceeded from 0 to 1.4 percent of the time with the greatest frequency at station #4 and the least at station #5. Greatest concentrations of hydrogen sulfide occurred at stations #s 1 and 4, namely, 30 pphm or greater.

Several odor incidents occurred during the survey period. Hydrogen sulfide levels measured during the time that objectionable odors were reported by citizens exceeded the olefactory threshold concentration (Table 4). There was good agreement between complaint areas and hydrogen sulfide measurements obtained at sampling sites representative of the complaint areas. The number of complaints generally agreed with the persistance of relatively high concentrations of hydrogen sulfide. Hydrogen sulfide levels ranged from 2.2 to 12.5 pphm for 7 consecutive hours on the morning of June 3, 1964, namely, 0200 to 0900 hours and 26 odor complaints were registered. Paint damage occurred during the evening of June 1, 1964 when the hydrogen sulfide concentration was 30 pphm for at least 1 hour.

Table 4. HYDROGEN SULFIDE CONCENTRATIONS ON DAYS OF RELATIVELY LARGE NUMBERS OF ODOR COMPLAINTS, PPHM

Date	Time	Sampling sites					No. of complaints	Boundry of complaint area
		1	2	3	4	5		
5/19/64								
	2300-2400	3.0	N	-	-	N		
5/20/64	Morning						16	13th, 20th, Liberty, Ohio and Prairieton, Harrison 8th, Preston
	0000-1000	4.0	N	-	-	N		
	0300-0400	>30	N	-	-	N		
	0400-0500	30	N	-	-	N		
	0500-0600	4.0	N	-	-	N		
5/23/64								
	2100-2200	N	0.9	-	N	N		
	2200-2300	N	0.6	-	N	N		
	2300-2400	N	0.4	-	N	N		
5/24/64	Morning - Afternoon						28	Prairieton, Harrison, 8th, Helen
	0000-0100	N	0.2	-	-	N		
	0100-0200	N		-	N	1.5		
	1000-1100		4.1	-	-			
	1100-1200	N	1.8	-	-	N		
	1400-1500	0.4		-	-	N		
	1600-1700	0.2	N	-	-	N		
	1700-1800	0.9	N	-	-	N		
	1800-1900	N	N	-	-	0.8		
	1900-2000	N	N	-	-	1.2		
	2000-2100	0.6	N	-	-	N		
	2100-2200	0.4	N	-	-	N		
	2200-2300	0.2	N	-	-	N		
5/26/64	Afternoon - Evening						7	3rd, 9th, Washington, McKeen
	0200-0300	N	-	2.6	1.3	N		
	0400-0500	N	-		0.2	N		
	0500-0600	N	-		2.2	N		
	1000-1100	N	-	0.2	N	N		
	1300-1400	N	-	0.3	3.4	N		
	1400-1500	N	-	0.1	0.5	N		
	1600-1700	N	-	0.8	N	N		
	1700-1800	N	-	1.0	N	N		
	1800-1900	N	-	0.8	N	N		
	1900-2000	N	-	0.6	N	N		
	2000-2100	N	-	0.2	N	N		
	2100-2200	N	-	0.6	N	N		
	2200-2300	N	-	0.6	N	N		
	2300-2400	N	0.1	0.9	N	N		
5/27/64	Morning						4	1st, 6th, Hulman, Helen
	0000-0100	N	0.8	1.0	N	N		
	0100-0200	0.2	0.6	-	N	N		
	0200-0300	0.4	N	-	N	0.2		
	0600-0700	N	N	1.6	N	N		
	0700-0800	N	N	0.3	N	N		

Table 4 (Continued)

Date	Time	Sampling Sites					No. of complaints	Boundry of complaint area
		1	2	3	4	5		
/1/64	Afternoon						2	3rd, 29th, Washington, Willow
	1500-1600	L	N	-	0.4	N		
	1600-1700	L	N	-	1.1	N		
	2200-2300	L	N	-	1.0	N		
	2300-2400	L	N	-	30.0	N		
/2/64	Morning						7	Jefferson, Vorhees, Dillman, Turner
	0000-0100	L	-	-	1.2	N		
	0600-0700	L	-	-	6.2	N		
	0900-1000	L	-	-	0.6	N		
/3/64	Morning						26	3rd, 9th, Crawford, Greenwood
	0100-0200	L	-	-	-	0.1		
	0200-0300	L	-	-	5.0	N		
	0300-0400	L	-	-	12.5	N		
	0400-0500	L	-	-	10.1	7.0		
	0500-0600	L	-	-	2.2	9.0		
	0600-0700	L	-	-	2.8	3.9		
	0700-0800	L	-	-	0.7	3.9		
	0800-0900	L	-	-	0.5	2.8		
	0900-1000	L	-	-	0.4	N		
	2000-2100	L	3.7	N	N	N		
	2100-2200	L	4.4	N	0.6	N		
	2300-2400	L	N	N	0.5	N		

N - Negligible, less than 0.2 pphm
Dash - Sampler inoperative
L - Samples were collected but tape record was lost

METEOROLOGICAL CONSIDERATIONS

A close inspection of meteorological records from Hulman Field, about 6 miles east of the Wabash River in Terre Haute, for the period May 15, 1964, through noon, June 12, indicates a likelihood of a strong low-level or surface-based inversion accompanied by light winds or calm conditions on 13 of the 28 nights. On many of these nights at least one observation showed calm, with minimum recorded speeds of 6 mph or less on the other nights. At very low speeds it is difficult to determine wind directions at any point where measurements are not actually made. However, in an area of relatively flat terrain, such as Terre Haute, the wind record at an airport with an open exposure should give a basic flow on which to superimpose local effects such as channeling or drainage effects in a shallow valley.

The Wabash River extends from the north-northeast and north of the city, then southward along the western boundary of Terre Haute, and thence to the south-southwest, with lower terrain to the south-southwest (Figure 1). An east-west cross-section of the valley shows a quick drop of about 45 feet from the city level to the river, then nearly level westward about $1\frac{1}{4}$ miles to a less abrupt rise marking the western boundary of the valley itself. A nighttime drainage wind would be toward the south-southwest, though very weak and easily overcome by a southwesterly wind.

On some of the inversion nights, the reported wind at the airport would tend to reinforce the drainage wind. On some other inversion nights the wind was from the south-southeast or southeast. While opposed to the drainage effect this would not likely have much effect on the

river bottom near the city because of the terrain. On other inversion nights, wind conditions were either doubtful or definitely unfavorable for transport of pollutants from the valley over the city. However, on several nights, most notably May 18-19 and June 3-4, and less so on some other nights inverson and wind conditions were favorable for transport of pollutants from the valley area over the city.

The character of a source of effluents is of great importance during inversion conditions. From an elevated source, a plume will level off near the effective source height and not be apparent at the surface until "fumigation" occurs as the temperature increases after sunrise. For a ground-level source, the problem is more complex, as it depends on the temperature of the source relative to the ambient temperature. For a cool source (temperature not warmer than the air) the effluent will tend to remain at ground level, and if in a depression such as a valley, perhaps become highly concentrated. For a warm source, however, an effective source height becomes apparent, with some of the characteristics of an elevated source. Some sources, however, such as a lagoon, present a still more complex problem, as the air temperature varies above and below the source temperature. For such a source, under nighttime inversion conditions, the pattern of diffusion would be the following over a 24-hour period (ignoring general wind transport for the moment):

Afternoon: cool source (lagoon) surrounded by warm earth surfaces; the effluent spreads outward near the ground, then becomes mixed and transported upward in rising thermal currents,

Early evening: source still cool but air stabilizing; effluent tends to fill the depression, or valley, in which the lagoon lies, but does not diffuse upward because of the forming atmospheric temperature inversion,

Later evening: as the air temperature reaches the source temperature a near maximum concentration would be found in the immediate neighborhood of the source,

Nighttime: warm source surrounded by cool air; a weak chimney effect becomes established, with the air above the source rising slightly and being replaced by cooler air from the surroundings. The maximum concentration will now be found immediately above the source, at an elevation depending upon the temperatures prevailing. This concentration may build upward sufficiently to move out over higher surrounding terrain, while ground level concentrations near the source fall off,

Morning: the chimney effect disappears; pollutants accumulated aloft may be brought down to the earth (fumigation) as the source again becomes thermally neutral,

Afternoon: a return to the original condition.

These phases of the local circulation are illustrated in Figure 3A-D. This circulation is a miniature of the well-known sea-breeze effect, and due to the small scale very weak and even with a rather light general wind along the valley may not be perceptible. With a light cross-valley general air flow, however, the wind under inversion conditions tends to stay above the valley so that this circulation is not inhibited.

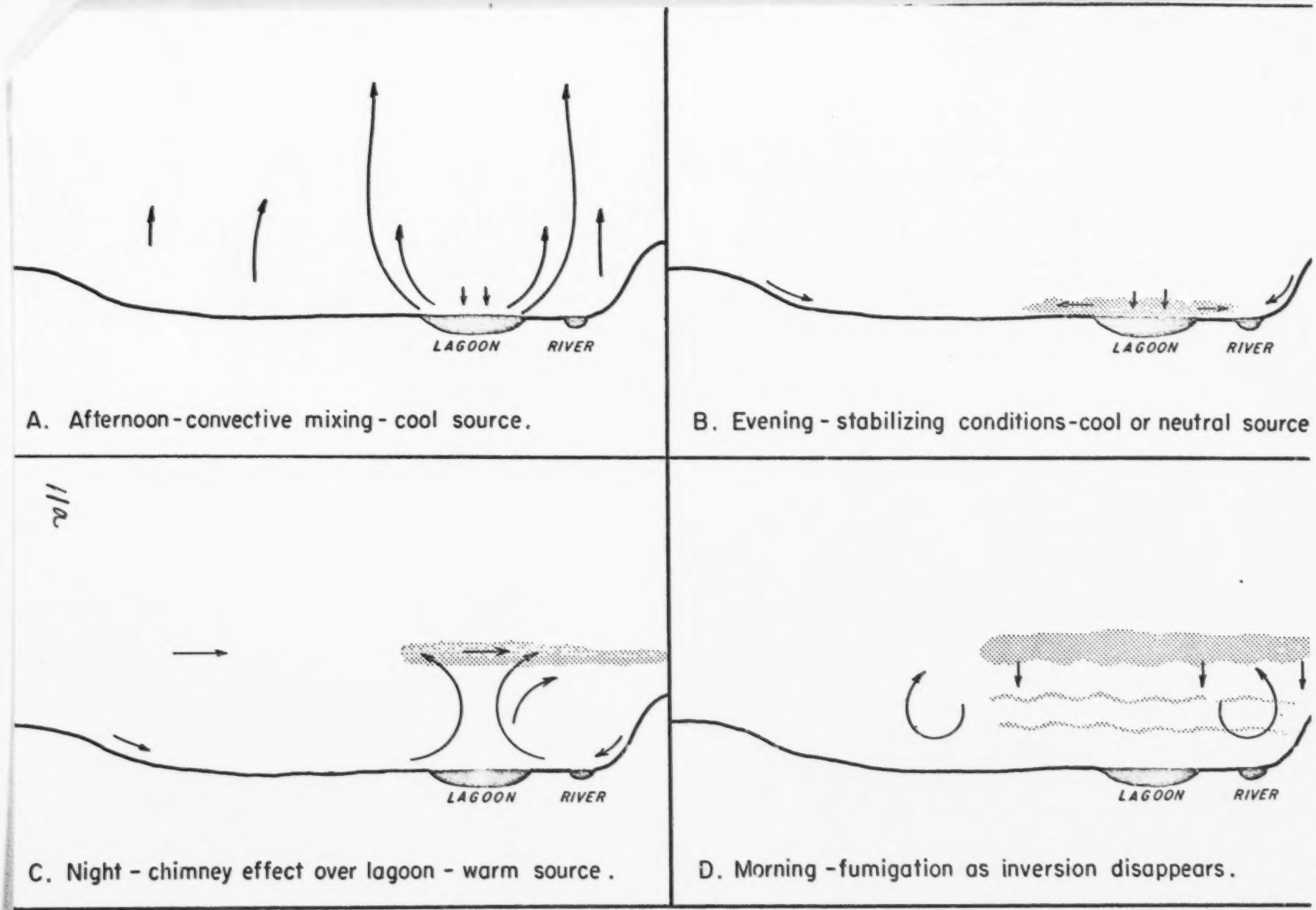


FIGURE 3. DIURNAL VARIATION OF CIRCULATION OVER LAGOON.

A cross-valley flow, moreover, may be able to pick up a portion of the effluent cloud, or cause the entire cloud to drift over the higher ground, thus causing strong ground-level concentrations over the terrain adjacent to the valley.

With the above discussion in mind it becomes apparent that any emissions from elevated sources would not produce high nighttime ground-level concentrations, but could produce fumigation conditions shortly after sunrise. On the other hand, ground-level sources would produce greatest atmospheric concentrations during the period of stable atmospheric conditions as is characterized by temperature inversion and low wind speeds which often occur at night. Greatest atmospheric pollutant levels due to emissions from the lagoon would occur in Terre Haute during nighttime under inversion conditions and light southwest to northwest winds. Such a condition existed on the nights of May 18-19 and June 3-4, and to a lesser extent on certain other nights during the survey period.

MEDICAL ASPECTS AND PUBLIC DISCOMFORT IN THE CITY OF TERRE HAUTE
(Work performed solely by U.S. Public Health Service personnel)

On May 20, 1964 a U.S. Public Health Service physician conducted an initial investigation of conditions that were reported to be caused by foul odors and other air pollution. Bad tasting water had also been reported. Symptoms of nausea, vomiting, diarrhea and shortness of breath had been reported by citizens living in the affected areas. The Mayor of Terre Haute had received four letters of complaint and twenty-nine telephoned complaints on May 20, 1964. Eighteen persons listed nausea caused by the odor as their chief complaint. Three of the letter-writers complained of vomiting, diarrhea, nausea, shortness of breath, and alsc bad-tasting water. The rest of the complaints concerned foul-tasting water or property damage.

Contact was made with the City and the County Health Departments. Neither had knowledge of any increased incidence of illness of any type, of respiratory disease, of hospital admissions or mortality, or of an increased number of visits to local physicians for any illness.

The physician visited both hospitals in the city. At Union Hospital (254 beds) located at North 7th Street, which is outside the most severely affected area of the city, admissions and emergency room records showed no unusual departure from normal. One patient from an area not severely affected by air pollution who had nausea, vomiting, and diarrhea with abdominal cramps complained of an irritating odor. She had been treated symptomatically on May 19. The admissions records at Saint Anthony Hospital (299 beds) located on South 6th Street, which is in the affected area, showed nothing unusual for the period May 4-20,

1964. However, the emergency room staff had treated one person for nausea and vomiting, 2 for choking and coughing, 2 for sore throat, and 4 for chest pain during the period of May 15-20. This information was abstracted from the emergency room log book. Five Union Hospital employees were reported to have become nauseated and fainted during a period of more severe pollution.

This brief investigation failed to uncover any grave physical illness that could be directly related to air pollution. However, the frequency of complaints of nausea with or without vomiting from residents who lived in the most severely affected areas was noted. The vile odor observed by the physician near source #3 led him to believe that possibly the odor could be the cause of the nausea and vomiting, provided that it was the same odor that was present in the affected areas of the city. Certainly nausea is more than merely a nuisance since it interfers with physical comfort, appetite and general well-being.

After the Public Health Service physician returned to Cincinnati, the Service received lists of names, addresses, and nature of complaints from Terre Haute residents who had called or written to the Mayor, the police or city health officials on May 20, 21, and 24, 1964. After a study of these, and after evaluation of conditions in Terre Haute, it was decided that further investigations should be made.

On June 2, Public Health Service epidemiologists conferred with some of the State Department of Health personnel in Indianapolis. The subject was the health problems in Terre Haute resulting from the air pollution situation which had occurred around May 19 & 20 and were repeated subsequently.

At that time the chief of chronic illness program told us that we could go in and study the situation that very day if we so desired.

Upon our return, we were given the information that on the night of June 2, the situation had worsened in Terre Haute.

On the morning of June 3, 1964 the Mayor's office in Terre Haute received approximatley 20 more telephone calls complaining about odors in the community, property damage--specifically discoloration of house paint, and discomfort of residents of the affected area of the city, and shortness of breath. A few complaints of asthmatics whose conditions were made worse by the irritating pollution were also received. This latter group of complaints associated with the high hydrogen sulfide levels on June 3, 1964 indicated a repetition of the previous air pollution episode of May 19 & 20. They stressed not only property damage and its consequent economic loss but also a continuing situation that involved general discomfort, nausea, respiratory tract irritation, and possibly shortness of breath in a few susceptible individuals with previously existing heart or respiratory disease. It was thought likely that symptoms of nausea and revulsion from unpleasant odors do not usually compel people to seek attention at a hospital or at a doctor's office. Home remedies and non-prescription treatment are the more usual avenues of relief from symptoms. Seven of the 19 persons had taken medication for symptomatic relief. One person contacted a physician.

In view of the paucity of medical information, the recurrence of the air pollution situation on the night of June 2, and the acceptance

of our activities by the State Department of Health, we returned to Terre Haute on June 3. The following were considered necessary and could be carried out in the short period of time at hand.

1. An investigation of complaints about odor and the possible health effects of the causative pollutants.
2. The mortality records for the period February, March, April and May, 1964 were obtained from the City Health Department.
3. A study of absenteeism of personnel in Union Hospital in Terre Haute was carried out.
4. An investigation of emergency room records of both Terre Haute hospitals for the months of April and May, 1964.

The investigations were made by a physician epidemiologist and an epidemiologist of the U.S. Public Health Service. They arrived in Terre Haute to begin the investigation on the evening of June 3, 1964 having been thoroughly briefed by those previously involved in the investigation. They proceeded to make a tour of the affected areas of the city. They, themselves, experienced nausea and throat irritation during the tour. The major affected area was a middle class part of the city containing some older and large but well-kept houses occasionally showing evidence of recent painting and other repairs. Some houses showed dark streaking of their paint that was consistent with hydrogen sulfide damage. One of the investigators stayed at the police telephone-board for two nights to talk to anyone who called to complain of air pollution. Only one complaint of odor was received with no mention of paint damage or health effects.

The investigators made several trips through the city during the night of June 3, 1964. While they found the obnoxious odor easily

recognizable, no complaints were received. At this time the northwest part of the city was more affected than the southwest by the odor.

Lists of complaints received by the Mayor, the police, the Board of Health, and U.S. Public Health Service representatives (who were working out of the Terre Haute sewage treatment plant) were investigated (Table 5). Health effects complaints included those referring to nausea, vomiting, headaches, diarrhea, throat irritation, with or without additional complaints referring to property damage.

Table 5. Complaints Referring to Property Damage/Odor and Health Effects/Odor

Date	Property/odor	Health/odor	Total
May 20, 1964	1	15	16
May 21, 1964	1	4	5
May 24, 1964	14	14	28
May 26, 1964	6	0	6
May 27, 1964	4	0	4
June 3, 1964	14	8	22

The investigators interviewed, by telephone, 20 persons from among those who complained of health effects. A short questionnaire was designed for the purpose. A city map showing health complaints was plotted, Figure 1. Both property and health effect complaints have a similar distribution in the community. Although complete aerometric data were not then available, the investigators during their own exposure to the air in various parts of the city believed that the distribution of complaints followed closely their subjective estimates of what were the more severely

polluted areas of the city. The concentration of complaints is greatest in the southwest part of the city and gradually decreases toward the northwest.

Results of interviews with complainants are summarized as follows:

1. There was an excess of females in the ratio of 2 to 1.
2. Of the 20 persons interviewed by phone, 95 percent reported experiencing symptoms associated with air pollution preceived as odor. Of a total of 65 individuals of all ages in the 20 households, 37 or 57 percent were reported to have symptoms.
3. Nineteen, or 95 percent of the 20 persons interviewed believed there was an air pollution problem where they live.
4. Most affected individuals mentioned more than one symptom. Thirteen complained of nausea, the most commonly encountered symptom; five complained of being awakened at night; five reported burning of eyes, and four, shortness of breath. Other less common symptoms reported were cough, headache, anorexia, acute asthma attack, nervousness, weight loss, diarrhea, fever, gagging, heaviness in the chest, etc.
5. Only 8 of the 20 did not specifically list gastrointestinal symptoms.
6. There were no apparent differences in severity or multiplicity of symptoms when the elderly were compared to the young.
7. Seven of the 20 persons interviewed were taking medication for some pre-existing medical problem.
8. Seven of the 19 persons who reported symptoms had taken proprietary medicines for symptomatic relief. Only one had consulted a physician for treatment.

9. The symptoms were usually short in duration and ceased when the odor became weaker or disappeared.

The investigators were of the opinion that none of the complainants were responding to solicitation by any city official. There was no evidence to reject the possibility that the symptoms were not causally related to the odor-air pollution problem in Terre Haute.

From these interviews of complainants, it appears that distressing symptoms followed exposure to polluted air in the more severely affected areas of the city. The greater the degree of pollution as subjectively experienced by the complainants and by the Public Health Service investigators, the worse the symptoms were. While the symptoms were not severe enough to cause the complainants to seek medical attention, self-medication by those affected was common. Obviously the pollution and specifically the odor were more than nuisances. General well-being was affected, albeit not severely enough to seek a physician's help. The symptoms were unpleasant and uncomfortable. Ten physicians who were contacted in Terre Haute agreed with the inhabitants complaining to city officials or agencies that the city's malodorous air pollution problem caused nausea, sleep disturbances, loss of appetite, a distressing physical and emotional environment in which to live, and property damage.

Death registrations were reviewed for Terre Haute for February, March, April, and May of 1964. Only those cases were noted in which asthma, bronchitis, emphysema, bronchiolitis, etc. were reported as either primary or contributory causes. Four deaths were recorded during April and May, 1964 whereas there were no deaths recorded of these particular chest diseases during the months of February and March which are the high risk months.

All but one of the deceased resided in the area of Terre Haute. The non-resident death was an infant. The number of deaths are too small to permit any conclusions and the data are incomplete since they lack autopsy confirmation. In view of the differences in the number of deaths, even though few occurred between February, March and April, May of this year 1964 further examination of deaths in previous years, for the same causes, are indicated.

An unusually high number of absentee-days occurred during the month of May among the personnel of Union Hospital. A list was prepared by the hospital showing 11 persons with a total of 15 absentee-days. This absenteeism was attributed to nausea and/or abdominal cramps and/or vomiting. Seven of these individuals were contacted. Three of the seven were probably sick with a gastroenteritis. One thought she might be pregnant, 2 others felt their discomfort was due to dysmenorrhea. In only one instance could a possible air pollution effect not be ruled out.

Emergency room records for the months of April and May were reviewed at St. Anthony's Hospital in the southwest section of town and Union Hospital in the northwest section. Complaints listing nausea, vomiting and/or respiratory symptoms were tabulated. No significant or unusual incidence in total number of patients with symptoms in these categories was noted during either period at either hospital.

On June 11, 1964, the Public Health Service physician presented a statement to the Health Officer of the City of Terre Haute. They discussed the health implications of the pollution episodes. Summarizing the findings in Terre Haute, it was stated that the investigation suggested the presence of an air pollution problem with greater than nuisance value.

During the periods of highest pollutant concentrations many persons, including physicians in Terre Haute, reported symptoms which were associated in time sequence with high pollution levels and which they, in their opinions, attributed to acute pollution episodes, that is to the times when the odor in the air was especially unpleasant. These symptoms included nausea, loss of sleep and abrupt awakening, shortness of breath and headache and other less prominent symptoms. Almost none of the complainants had symptoms severe enough to require a physician's attention. However, the high concentrations of pollutants measured in Terre Haute have a real potential for severe health effects especially in the very young, the elderly and the infirm. Such air pollution-susceptible individuals as asthmatics, bronchitics, heart disease and emphysema patients, have a high risk of exacerbations and complications if pollutant levels associated with the recent episodes reoccur or rise to higher levels. At present the situation cannot be considered a "medical disaster." However, it should be stressed that the odors caused more than a mere nuisance. These opinions were also reported at a meeting with the city's Mayor and other city, state, and federal health authorities and the press.

Summary of Medical and Public Discomfort Aspects

Episodes of increased air pollution characterized by a foul odor in southwest Terre Haute have occurred. The odor was identified, at least in part, as that of hydrogen sulfide. At some point in this rise of air pollution levels the symptom threshold was reached and property damage resulted. At the threshold level numerous complaints were received by

the Mayor, the police department, and various health officials. House paint was streaked by the pollutant; the odor was unpleasant and objectionable and barely tolerable from the point of view of the physical and emotional well-being of many persons residing in the affected areas of Terre Haute.

Many physical symptoms were experienced by complainants. Chief among these was nausea followed by disturbed sleep, and shortness of breath. Few had symptoms severe enough to warrant consultation with a physician. No excess morbidity was noted. A possible increased absenteeism at one of the City's hospitals was suggested during this episode. The hospital emergency rooms experienced no increased incidence of illness that could be related to air pollution.

Persons who complained were interviewed by telephone. They felt that their symptoms were caused by air pollution. Those physicians who were interviewed in Terre Haute believed air pollution was responsible for symptoms experienced in the affected area of the city. The U.S. Public Health Service medical investigators are of the opinion that the obnoxious odor was the likely cause of certain symptoms in exposed individuals. However, those with symptoms rarely sought medical aid. There is potential danger for certain groups of susceptibles notably infants, the aged and the infirm should pollution levels associated with the recent episodes occur frequently in the future or if higher levels are encountered. It may be true that nausea has many possible etiologies: physical, including chemical effects on tissues; and psychological, that is intolerance to an extremely objectionable stimulus from whatever source.

But no matter which etiology is most important here, nausea will be no less unpleasant. It must be more than coincidence that would motivate so many people to complain of nausea at the same time. The repetitiveness of the pollution episodes, concomitant complaints of symptoms when pollutant levels rise, and the existence of relatively stable atmospheric conditions in each instance give further support for confirmation of an air pollutant etiology for the complaints of the community. To debate whether or not a medical or public health problem exists in Terre Haute caused by high air pollutant levels is an academic exercise. People are discomforted and their distress is caused by unpleasant symptoms of which nausea is the chief one. The people attribute their symptoms to the odors blanketing their city. People do not have to die to prove that a medical or public health problem exists, nor must they be hospitalized or seek medical assistance in sufficient numbers to attract attention before action is justified.

There is an air pollution problem in Terre Haute. It is not a 'medical disaster' but it may have the potential of becoming one in the future. An adequate air pollution control program and relevant health studies would seem to be mandatory from a Public Health viewpoint.

SUGGESTIONS FOR AN AIR POLLUTION CONTROL PROGRAM

The severe air pollution problems that Terre Haute has recently experienced as well as the severe problem which occurred about a year ago are clear indications of the need for an effective air pollution control program. The sources of pollution involved in these two extreme cases, as well as a number of other existing pollution sources and those that may be established in the future should be subject to appropriate regulation by the local government to correct existing problems and to prevent future difficulty. It is not fair to either the citizens or to those responsible for pollution sources to wait until conditions become unbearable before acting. Delay also leads to strained relationships and may lead to ill-advised action. The local government has a responsibility to organize, finance and operate a program which will: provide for monitoring of air quality; bring about public understanding of air quality and air quality goals; prevent undesirable pollutant emissions in the future; and bring about corrections when needed. Technical assistance from outside the community may provide specialized competence as necessary but it is not a substitute for local organization and acceptance of responsibility.

The air pollution control law adopted by the Indiana State Legislature in 1961 has the declared intent that primary responsibility for the control of emission of air contaminants into the atmosphere shall rest with local governmental agencies. The law provides that the State government shall encourage and assist local air pollution control agencies and do other things. However the State may, under certain specified conditions, invoke its authority to require abatement of problems.

The air pollution problems of major concern at this time in Terre Haute are those caused by hydrogen sulfide and other odorous pollutants. These should receive early attention in the control program. As the program proceeds, other objectional pollutants can be actively evaluated and controlled as may be found necessary. An outline for suggested activities is as follows:

1. Review and revise as necessary the air pollution control ordinance of Terre Haute. As revised, the ordinance should:
   a. Designate the agency responsible for air pollution control and specify the powers and duties of such agency as necessary to conduct a modest but adequate air pollution control program.
   b. Provide for an air pollution control board and specify its powers and duties.
   c. Establish an ambient air quality standard for hydrogen sulfide of 5 pphm for one hour.
   d. Require that approval be obtained from the air pollution control agency before construction work or alterations, which may cause air pollution, may proceed.
   e. Establish allowable emissions of smoke, flyash and odorous materials; prohibit open burning of refuse and creation of nuisances; and provide penalties for failing to meet requirements.
   f. Require submission to the air pollution control agency of information about sources of pollution.
   g. Provide for cooperation between the air pollution control agency and other city agencies, especially those responsible for building regulation, planning and zoning.

The present ordinance provides for some of these items. These should be reviewed and revised as found appropriate.

2. Continue hydrogen sulfide and meteorological measurements.

   a. Continue operation of lead acetate impregnated strip filter paper samplers for measurement of hydrogen sulfide on a 24-hour per day basis at four stations until July 1, 1964.

   b. Continue operation of the meteorological equipment at the sewage pumping station until July 1, 1964.

   c. Continue measurements of hydrogen sulfide with the detector tube sampler at locations close to and downwind of major suspect sources. Samples should be taken at least once per day, preferably at night. More samples should be taken if concentrations greater than 1.0 ppm are found.

   d. On July 1, 1964, evaluate the situation. If the hydrogen sulfide problem has been eliminated, the sampling program could be greatly reduced. One strip filter paper sampler could be operated at a strategic location and only those samples showing concentrations of hydrogen sulfide of concern would be quantitated. The meteorological station could be shut down. Detector tube samples would be taken only as indicated by needs. If the hydrogen sulfide problem is not abated, measurements should be continued and further steps should be taken to bring about control of hydrogen sulfide emissions to the atmosphere.

3. Provide personnel and funds necessary to carry on the air pollution control program including work in air quality monitoring, abatement,

plan approval, public information complaint investigation, pollution source inspections, etc.

4. Consider the need for control of air pollution sources located outside of, but close to Terre Haute. If a need is found, it may be appropriate to make efforts to interest other municipal governments or the county government in air pollution control work.

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